

# A Case of a Power Failure in the Operating Room

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In the operating room, safely administering anesthesia amidst a major power failure can instantly present one with a formidable challenge. A case is presented involving a 23-year-old healthy woman who underwent a complex oral and maxillofacial surgery to correct a dentofacial deformity. Three hours into the case and with the patient's maxilla downfractured, the overhead surgical lights blacked out, and there was an apparent loss of the anesthesia machine's ability to function. Providing adequate oxygenation, ventilation, anesthesia levels, monitoring of vital signs, and transportation of the patient were some of the challenges faced, and the response to this unexpected event is recounted. The importance of one's familiarity with an anesthesia machine's backup battery supply, routinely checking machinery, ensuring that appropriate and sufficient supplies are readily available, exercising calm leadership with clear communication, and formulating a clear plan with backup alternatives are discussed. Various recommendations are proposed with respect to the preparation for and the prevention of a power failure in the operating room. This report's account of events is aimed to "shed some light" on this topic, serve as a check of one's own preparedness, and facilitate the optimal management of a similarly unexpected incident.

**Key Words:** Power failure; Battery supply; Ventilator; Transport monitor; Total intravenous anesthetic; Recommendations.

During a hot midsummer's day in 2003, an estimated 50 million inhabitants of New York City, multiple surrounding states, and parts of Canada experienced one of the largest blackouts in history. The impact of the power loss was omnipresent. In the operating room, safely administering anesthesia amidst a major power failure instantly presented a formidable challenge. This report will recount the immediate response to this unexpected incident and propose several recommendations for the preparation and management of any similar future occurrences.

A 23-year-old healthy woman entered the operating room to undergo a complex oral and maxillofacial surgery to correct a dentofacial deformity. The planned procedure was a Lefort 1 osteotomy, bilateral mandibular osteotomies, and a genioplasty. We placed 2 peripheral intravenous lines and inserted a radial arterial

line to closely monitor blood pressure. We included deliberate hypotension in the anesthetic plan to minimize intraoperative blood loss. Next, we induced the patient with intravenous medications and nasally intubated her without complications. General anesthesia was maintained with nitrous oxide and oxygen, isoflurane, and vecuronium, as well as a supplemental infusion of remifentanyl.

The procedure was progressing smoothly until the third hour of this scheduled 8-hour case. The overhead lights suddenly flickered, and all the individuals in the operating room sensed a noticeable surge of power. The ventilator, anesthesia monitors, compurecord, and surgical equipment all continued to function normally, and for the next 20 minutes the surgery continued without interruption. However, the air conditioning seemed to have been lost, indicated by the visible condensation accumulating on the room's door windows and the temperature increasing within the operating room. Moments later, the overhead procedure lights went out, leaving surrounding fluorescent lights to provide only dim lighting within the room. We summoned anesthesia

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technicians to provide information regarding the backup battery supply to the anesthesia machine and to collect flashlights and extra batteries to improve the lighting for the surgical and anesthesia teams. Telephone communication had not been jeopardized, and at this point we learned that a massive power outage was affecting the area. Inside the operating room, despite the continuously functioning surgical and anesthetic equipment, the lighting and temperature were noticeably compromised, and the electrical supply to our building appeared dubious. It was time to quickly prepare for an even worse situation.

Patient ventilation was the primary concern. We connected a manual bag-valve resuscitation device to the supplemental oxygen source on the anesthesia machine. Minutes later, the operating room went completely black—except for the colored lights of the digital displays of the ventilator and patient monitor. The power source to the anesthesia machine and incorporated patient monitor was functioning, independent of the room's power supply. The ability to automatically monitor the patient's vital signs had not been affected. However, in the very poor lighting of the room, it had appeared that the bellows were not moving. Our initial reaction was that the ventilator had most likely failed. We immediately disconnected the patient from the ventilator's circuit and used the recently connected manual resuscitator bag to manually ventilate with 100% oxygen. Ventilation was confirmed by manual auscultation of equal and bilateral breath sounds. Content with our ability to successfully ventilate the patient through a secured airway (nasotracheal tube), we then addressed the need to keep the patient adequately anesthetized. With an uncertain ability to deliver inhalational agents, and an infusion of remifentanyl electrically powered, we discontinued these modes of anesthetic delivery and used a total intravenous anesthetic (TIVA). Ventilated manually with oxygen, the patient was sufficiently anesthetized with incremental intravenous boluses of propofol and fentanyl. At this time, the compupercord's ability to record data had been lost. Consequently, we used a manual anesthesia record for the remainder of the case. During this time of urgency, the surgery was temporarily suspended and the patient's vital signs, which were continuously monitored by the anesthesia machine, remained stable.

After 5 minutes of manual ventilation and TIVA in the darkened operating room, the requested flashlights became available. Now able to better visually assess the situation, we established that the machine's oxygen and nitrous sources were adequate, confirmed by their appropriate wall pressures. We then reconnected the patient to the anesthesia machine circuit and manually ventilated with 100% oxygen from the wall source. Add-

ing nitrous and isoflurane, we manually ventilated the patient with a fresh gas mixture, confirmed by the machine's functioning oxygen sensor and the gas analyzer's corresponding end tidal values for carbon dioxide, nitrous, and isoflurane. With the hospital's active scavenging system still intact, the room would not be contaminated with anesthetic gases. Constantly noting our capabilities, we turned the ventilator on, which responded favorably. The patient was now ventilated and anesthetized with the anesthesia machine, powered by its backup battery that was independent of the operating room's backup power supply. We discontinued the TIVA approach and maintained the patient with 0.3% isoflurane, 67% nitrous, and 33% oxygen while we contemplated the surgical plan.

At this point in the surgery, the patient's maxilla had been downfractured (ie, separated from the base of the skull). Considering that the electrosurgical unit and electrically powered hand piece were no longer functioning, that an estimated 5 hours of surgery remained, and that it was uncertain when the room's electrical supply would be properly restored, the anesthesia and surgical teams made a unanimous decision to abort the surgery as soon as possible and complete it under more ideal conditions at a later date. As the surgeons focused on achieving hemostasis and temporarily fixating a "floating" maxilla, new concerns regarding patient safety and anesthesia delivery had emerged.

The time line for the restoration of power was unpredictable; therefore, it was equally uncertain when this surgery would eventually be completed. The future anesthetic management of the patient necessitated consideration, specifically the risks and benefits of extubation. Extubating the patient's trachea at this time did not seem to be prudent for a variety of reasons. The practical and psychological implications of a patient emerging from anesthesia with a fragile maxilla were clear causes for concern. Furthermore, because significant surgical swelling had developed, extubation at this time would limit the ability to reintubate should that become necessary. Moreover, there was the existing benefit of definitive control over the patient's airway, for it had been reliably secured with the nasotracheal tube. Thus, the risks of extubating the patient at this time clearly outweighed any possible benefits. Therefore, we decided that until such time when the surgery could be completed, the patient would remain sedated and intubated. We also decided that while the patient was sedated she would eventually be allowed to breathe spontaneously rather than remain paralyzed. Sedating the patient, who might not tolerate the nasotracheal tube but was at least breathing on her own, was a more favorable option than keeping her paralyzed and entirely dependent on a ventilator with a precarious power supply.

With the surgery completed (for the time being) and staff available to monitor the sedated and intubated patient overnight if necessary, the next consideration was whether to keep her in the operating room until power would be restored or to transfer her to another location. In the operating room, the patient had remained stable, never became light from anesthesia, and was thoroughly and continuously monitored. In short, her safety had never been jeopardized. Yet transferring her to a new location could introduce the risk of compromising her safety. The information regarding the power supply to the anesthesia machine and operating room solved this dilemma.

The anesthesia machine used in this case was the Datex Ohmeda S/5 ADU. The backup battery or uninterruptible power supply (UPS) was a TRIPP-Lite Smart Pro 700HG. According to the manufacturers' model specifications,<sup>1,2</sup> if the anesthesia machine's power usage is at a maximum (400 W), a full load is put on the UPS and 20 minutes of power would be available. However, if the machine uses one quarter of the maximum load, then an estimated 105 minutes of reserve power from the UPS would remain. It was difficult to accurately assess the load that the anesthesia machine placed on the UPS; however, we estimated a range of 20–105 minutes of available power from the UPS. Furthermore, if the power from the UPS were to become depleted, only the "right side" of the anesthesia machine (ie, patient monitoring) would be lost at that time. This is because the anesthesia machine contains an independently internal backup battery that could generate the "left side" of the machine (ie, vaporizers and ventilatory function) for another 20–30 minutes.

With this information, the amount of time to safely remain in our current location was limited. Consequently, seeking a destination with a more reliable power supply became the next concern. Unlike our building's failed generator, the one supplying the postanesthesia care unit (PACU) in an adjacent building had been consistently providing reliable and sufficient power. Furthermore, the PACU was fully staffed with experienced nurses and was able to accommodate our patient, making it the most ideal location for this patient's transfer.

Clear communication was essential to optimize a smooth and safe transport of the patient. Therefore, before altering the currently stable situation, the route and mode of transfer had to be clearly established and understood by all of those involved in the transfer. First, we informed engineers about our imminent move. A bridge connected to the adjacent building was illuminated and accessible from our location. It was also confirmed that a service elevator was operational and large enough to accommodate the patient's stretcher. Remaining cautious of the power supply, we requested 1

engineer to be situated on the floor from where we were leaving and 1 engineer to be situated on the floor to where we were heading 5 levels below in case assistance was needed should a power failure occur during transport in the elevator. Second, the PACU was made aware of our situation and was given a full report of the patient's medical and surgical history. The necessary monitors were readied, and appropriate ventilator settings were set up in anticipation of the transfer. Third, we connected the manual resuscitator bag to a full oxygen cylinder and used it in the transfer for oxygenating and ventilating the patient, and we checked and set up the transport monitor (Propaq, Skaneateles Falls, NY), which was capable of monitoring the patient's heart rate, respiratory rate, arterial blood pressure, and oxygen saturation. We made sure that the intravenous lines were functional and accessible, and we rechecked the integrity and security of the nasotracheal tube. Fourth, we drew up several medications. Midazolam and fentanyl would be used for achieving amnesia and sedation. Atropine, ephedrine, phenylephrine, labetalol, propofol, and succinylcholine accompanied the transport in case a situation arose that might warrant their use. We also carried laryngoscopes and various endotracheal tubes. Finally, with the patient fully monitored, an experienced staff standing by ready to accept the patient, and a defined route of transfer mapped out with backup personnel, 2 anesthesia attendings and 2 residents transported the patient safely and without incident to the more secure destination. After the successful transfer to the PACU, the patient remained sedated overnight with infusions of midazolam, fentanyl, and propofol. She breathed spontaneously and was assisted when necessary by the ventilator, which was set to the synchronized intermittent mandatory ventilation (SIMV) mode.

The next morning, the patient, who was still sedated and intubated, was brought to another operating room (in the same building as the PACU with the viable generator) and the surgery was completed. Once again, the patient remained sedated and intubated overnight. After her uneventful overnight postoperative period, no longer sedated and displaying favorable extubation criteria, she was extubated without difficulty the morning after her surgery was completed. She was informed of the events that had transpired during the previous 48 hours, of which she had no recall. Postoperatively, she did not demonstrate any anesthetic complications, nor did she develop any adverse sequelae from the extended period of sedation or operative duration.

The most valuable contribution an anesthesiologist can make in any emergency situation is to maintain his or her composure. This quality is crucial to properly assess the situation and devise an appropriate plan that

will successfully manage the crisis. During an urgent situation in the operating room, it is the anesthesiologist who must step up and display strong leadership. A person who is calm in manner, clear in communication, and controlled with directives will best serve all those involved. Providing direction with a calm and controlled tone will help diminish any panic in the room, establish a stable environment, instill others' confidence, and facilitate the plan into action. Clear communication in stressful situations sounds trite, but it is often not executed properly. Short, simple directives to others are most effective, and all commands should be subsequently confirmed to avoid any delays or misunderstandings. For every step in the desired plan, an alternative or backup plan that assumes the worst-case scenario should also be devised.

A massive power failure that adversely affects the operating room's ability to function is rare, and the available related literature is somewhat limited. Chamley<sup>3</sup> describes an operative power outage caused by construction work within the hospital; however, no recommendations of how to cope with such a situation are provided. Waydhas<sup>4</sup> provides guidelines for transporting critical care patients within the hospital and explains the importance of having capable physicians, necessary monitors, and emergency equipment specific to each case accompany the patient during transport. Holzman et al<sup>5</sup> explain the benefits of using simulators for the purpose of training residents and attendings in emergency situations. A scenario of an intraoperative power failure is mentioned, yet how the physicians were taught to deal with such a situation is not thoroughly detailed. Therefore, after experiencing such a unique event firsthand and noting the contribution made by Gaba et al,<sup>6</sup> we have formulated the following recommendations to help prepare those who may find themselves in a similar situation (Table).

If a power failure should occur, the extent to which a facility and its staff have prepared for such an unexpected event would probably be inversely proportional to the likelihood of an undesirable outcome. First, several equipment checks should become routine. Flashlights should be stocked in the drawer of every anesthesia machine. Operating room crash carts should be equipped with multiple flashlights and extra batteries. Routine checks of these vital components should be approached with the same vigilance as supplying the cart with medications or any other equipment. Oxygen sources and the ventilator must be checked every morning upon setup, and the immediate availability of a resuscitation bag must be confirmed. A portable, battery-operated monitor that displays electrocardiogram, blood pressure, and oxygen saturations should be readily available. All anesthesia machines should be equipped with

#### Recommendations for the Management of a Power Failure in the Operating Room

1. Be prepared. Check daily to ensure that carts are sufficiently supplied with flashlights and batteries and that emergency equipment (manual bag-valve resuscitation device, transport monitor) is readily available and operational. Know the anesthesia machine's backup power source (uninterruptable power supply) and its life span.
2. Assess ABCs. Collect flashlights. Suspend the surgery. Call for assistance.
3. Establish adequate ventilation and oxygenation.
4. Confirm patient monitoring. If electricity and a battery-powered monitor are unavailable, manually assess the patient's vital signs.
5. Establish a system of anesthesia delivery. Use a total intravenous anesthetic if inhalational method is questionable.
6. Agree with the plan either to continue or abort the surgery. Consider the duration of surgery remaining, patient stability, and power reliability.
7. Weigh the risks and benefits of extubation, specifically addressing any risk of a compromised airway.
8. Establish the safest location for postoperative care. Confirm the availability of space and equipment. Alert the receiving staff to prepare monitors and equipment in anticipation of the transfer.
9. Delineate a safe route of transfer. Designate backup personnel to provide manual assistance should mechanical transport become compromised.
10. Essential equipment for transport includes a manual bag-valve resuscitation device, a full oxygen cylinder, laryngoscopes, various endotracheal tubes, emergency and sedative medications, a patient monitor, experienced personnel, and flashlights.
11. If the patient is to remain sedated and intubated, consider no paralysis. Breathing should be spontaneous or assisted by a ventilator.
12. Remember to remain calm and in control. Clearly communicate the proposed plan to others. Prepare an alternative option for each step.

a backup supply of battery power (UPS). Regular, frequent inspections of UPSs should be scheduled to ensure that reliable power is available if necessary. Furthermore, it is essential that the anesthesiologist know exactly which parts of the machine are supplied by and dependent upon the backup power supply. The individual who operates the UPS should also know its life span. Ascertaining the length of time that the anesthesia machine can be self-sufficient is an important factor in deciding which location is the safest for the patient.

In the case of a power failure, as in any other emergency situation, the patient's airway is of prime importance. Securing the airway is essential, and one's ability to ventilate the patient must be reconfirmed. Help from others should be summoned as soon as possible, and alternative light sources and extra batteries should be obtained immediately. If the ventilator is not functioning mechanically, it will be necessary to use a self-inflating



manual ventilation device. One should also confirm the ability to deliver oxygen. If the anesthesia machine's oxygen sensor is not functioning or it displays a value of 0, an alternative wall source or oxygen tank is required in order to oxygenate the patient. While assessing the ABCs, the functioning capacity of the patient monitor should be determined. Readings for oxygen saturation, end tidal carbon dioxide, heart rate, and blood pressure should all be available on the existing anesthesia machine. If not, a battery-powered portable monitor should be used to obtain this information. However, in the case that no electronic device is available to monitor the patient, the anesthesiologist must use his or her clinical skills to competently assess the patient. Observing the color of the patient's lips and nail beds for signs of cyanosis will help verify adequate oxygenation. Manual end tidal carbon dioxide detectors and stethoscopes can be used to assess respiratory exchange. An assessment of the patient's pulse can be obtained manually, and a sphygmomanometer can be used to measure blood pressure.

Next, the ability to effectively deliver anesthesia by inhalational means should be evaluated. Gas analyzers and computerized systems both may fail, resulting in an unreliable assessment of gas delivery. If this is suspected, or in the event of a machine failure, a TIVA is an excellent alternative in order to adequately keep a patient anesthetized. A wide selection of medications is at our disposal to achieve this aim. In addition, TIVA is transportable if the patient needs to be transferred from his or her current location. The patient's medical history, significant details of the surgery, and the likelihood that the airway may become compromised upon extubation are factors that must be collectively considered before deciding whether extubation in the operating room is more favorable than keeping the patient sedated and intubated.

In addition, the decision needs to be made whether to keep the patient in the operating room or to move him or her to another destination. If the proposed location does not possess significantly safer conditions than the current one, it is not worth the risk of transportation. Therefore, the following features of a potential location need to be available before moving: physical space; functioning monitors and ventilators; ample and experienced staff; and, of course, a reliable power sup-

ply. Alerting the receiving staff and preparing the monitors should occur in anticipation of the transfer. Next, a safe route of transport needs to be delineated. If elevators are required, they must be established to be serviceable and large enough to accommodate the patient's bed and at least 2 transporters. Immediately before making the actual move, a secured airway, ventilatory apparatus, intravenous lines, and portable monitors should all be rechecked and functioning well. Furthermore, similar to the protocol for the transport of any ventilatory-dependent patient, sufficient sedative and emergency medications, various laryngoscopes and endotracheal tubes, and experienced anesthesia personnel must accompany the patient during such a transport to optimally manage an unexpected episode.

Although a power failure in the operating room is rare in theory, its practical implications warrant discussion. Routine checking of machinery, ensuring that appropriate and sufficient supplies are readily available, exercising calm leadership with clear communication, and formulating a clear plan with backup alternatives will synergistically maximize patient safety and alleviate stress from such an urgent predicament. To date, there are no official guidelines with respect to the preparation for and the prevention of a power failure in the operating room. We hope this account of events can "shed some light" on this topic, serve as a check of one's own preparedness, and facilitate the management of a similar emergency.

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